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NUMERICAL AND EXPERIMENTAL STUDIES ON MIXEDMODE SOLAR DRYER FOR COCOA BEANS

BY

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A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE DEGREE IN MECHANICAL ENGINEERING,

OBAFEMI AWOLOWO UNIVERSITY,

ILE-IFE, NIGERIA.

2016

ABSTRACT

a beans dried undeIn this study a mixed-mode solar dryer was numerically modeled. The modeled solar dryer was designed, fabricated and evaluated for its performance. This was with a view to optimizing the design of the dryer and hence improve the performance.

The mixed-mode solar dryer was numerically modelled for performance optimization using ANSYS software. The simulation is based on ANSYS solar load model. Based on optimized geometry obtained, a mixed-mode solar dryer was designed, fabricated and evaluated. The dryer was used to dry cocoa beans under free convective and forced convective (varied airspeed of 1.2m/s and 1.5m/s) drying. The drying was carried out during the wet and dry season of the year. Drying air temperature, ambient temperature, relative humidity, air velocity and drying time were measured until the beans reached equilibrium moisture content. Grade and physico-chemical test such as pH, acetic acid content and FFA of the dried beans were determined.

Results of the model show that temperature within drying chamber increases with increase in solar collector area and decreases with increase in drying bed height. Maximum solar energy is obtainable at solar collector inclination angle of 14˚. This angle corresponds to angle ranges $(\alpha-6.5) \leq \beta \geq (\alpha+6.5)$ of the earth polar system. The data obtained from the fabricated optimized dryer without loading were compared with numerically modeled dryer results with good agreement. The dryer dried 50 kg of wet cocoa beans to equilibrium moisture content within average drying period of 57 hours. Quality tests of the dried beans show that all the dried beans are grade 1, irrespective of drying method. However, Cocoa beans dried under forced convective process are more acidic with acetic acid value of 3.23 mg/g and 3.19 mg/g at airspeed 1.2 m/s and 1.5 m/s, respectively.

The corresponding acetic acidic value for cocor free convective process was 3.38 mg/g. The pH for cocoa beans dried under free convective is higher than forced convective drying. The FFA for cocoa beans dried under free and forced convective drying (at airspeed 1.2 m/s and 1.5m/s) are 0.4 mg/g, 0.42 mg/g and 0.43 mg/g, respectively. Hence, cocoa bean samples dried under free convective drying are superior. In addition, samples dried during wet-season have less free fatty acid and acetic acid content with higher pH value compared to dry-season dried sample. Hence, cocoa bean samples dried during wet-season are also less acidic than dry-season dried samples.

In conclusion, the study established that adequately modeled mixed mode solar dryer is a viable tool for extracting maximal energy from solar system of the earth planet. Mixed mode solar dryer is adequate to dry wet cocoa bean to safe moisture level irrespective of seasonal variation in weather condition of the year with good quality produce.

Keyword: solar dryer,cocoa beans,FFA,physico- chemical,ANSYS software.

Supervisor: Dr. S.O. Obayopo

No of pages: xix,126 pages

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Cocoa beans are seeds of *Theobroma* cacao (*Sterculiaceae* family). The seeds are product of perennial cash crop tree which mostly grow in countries in a belt between 10 ˚N and 10 ˚S of equator. Cocoa beans are found in the wet tropical forest climate of West Africa, Central and South America and Asia. There are three varieties of cocoa tree: *Trinitarios*, *Forasteros*, and *Criollos*. But among these three varieties Criollos has become negligible in world trade (Manoj and Manivannan, 2013).

Presently in the world, the largest cocoa producing countries in terms of annual production size are Cote d'voire, Ghana, Indonesia, Nigeria, Cameroon, Brazil, Ecuador and Malaysia (Fowler, 2009). Among all these countries, Nigeria is the fourth-largest cocoa producer in the world with annual production ranges between 300,000-350,000 tons per annum.

The end products from processing of cocoa beans are majorly consumed as food. Cocoa beans are used in the production of chocolate bars, milk chocolate, cocoa powder, cosmetics and pharmaceuticals, toiletries product and health benefits such as anti-carcinogenic, antiulcer etc. Cocoa is also a source of theobromine, shell fat and vitamin D. However the quality of the end product of cocoa processing is a function of how it is processed.

Processing of cocoa beans involves harvesting of cocoa pods, breaking of the harvested pods, fermentation of wet beans obtained from broken pods, drying of the fermented beans to safe moisture content of about 6 to 8 % for either storage or immediate use. Out of these processing steps, fermentation and drying are the most essential steps that determine the quality of the final product.

Fermentation process for cocoa beans begins the oxidative reaction in cocoa drying processes. The constringent factors of the fermentation process are to reduce the moisture content of wet

cocoa beans and to build the temperature of the beans to about 45 to 50 °C prior to drying process. This temperature range has great influence on the quality of the bean obtained as the end product of the processing (Ausaid, 2008).

Method of drying adopted is another determining factor that dictates the quality of the end product of cocoa beans processing. There are two methods usually adopted: sun-drying and artificial drying method. The method adopted in any of the two methods depends on some socio-economic considerations and prevailing climatic conditions (Fagunwa et al., 2009).

1.1 Statement of Research Problem

Drying of cocoa beans is the process of moisture reduction which aimed towards preparing the beans for increased market value. However, the quality of the dried beans is usually impaired due to erratic energy supply during the drying process. The two broad methods of drying (open-sun and artificial) the beans have their associated constraints.

Traditional sun drying is simple and cheap: not requiring the expensive mechanical devices used in the artificial dryers. However, the method faces some constringent such as high labor-intensive requirement, the problem of inconsistency in weather condition which is more pronounced during wet season and some adverse effects that are associated with cocoa beans being spread on ground (Lasis, 2014). Adverse effects such as contamination due to direct exposure to wind blow, dust, dirt, beans damage by rodent, insect etc. have been identified. The

longer drying time taken in drying cocoa beans to required moisture content necessitated the use of artificial method